Princeton Plasma Physics Laboratory

Vol. 18, No. 6 • December 19, 1996

Hotline

The Princeton Plasma Physics Laboratory is a United States Department of Energy Facility

TFTR Reaches Historic Milestone

Team Plans for Final Run on the Tokamak Fusion Test Reactor

The TFTR Outage Team

By Anthony DeMeo

In August, 1996, the Tokamak Fusion Test Reactor (TFTR) completed its longest and most exciting run period, embodying the world's first extensive series of deuterium-tritium (D-T) magnetic fusion experiments. Since November, 1993, nearly 20,000 plasma pulses have been logged, including shots that produced record-breaking levels of fusion power, with advances in other key plasma parameters as well. "It is unprecedented that a tokamak has been operated so successfully, for such a long period of time, without a major outage," said Rich Hawryluk, Head of the Tokamak Confinement Systems Department.

The TFTR outage completed early this month was also unique. It was the first time that work was performed inside the vacuum vessel following the extensive use of tritium. Substantial amounts of the radioisotope remained in the vessel at the end of the run, so work had to be carefully planned with all the necessary precautions. Before the vessel ports were opened, tritium was removed by a combination of techniques including bakeout, pulse discharge cleaning, and glow discharge cleaning. The gas was then processed by the tritium cleanup system and trapped in special containers.

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TFTR

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"Preparations for this outage worked extremely well. We were able to keep tritium concentrations extremely low, enabling us to open ports and make major modifications to internal hardware. This was a major technical challenge, entailing close coordination and cooperation among a whole host of organizations within the Laboratory," noted Hawryluk.

PPPL'ers celebrate the completion of TFTR's 1996 run period and outage activities during a recent party held in the Lobby.

One of the major accomplishments during the outage was the replacement of three major radio frequency (RF) launchers. These are radio antennas which introduce RF waves into the plasma. The waves heat the plasma directly, or drive plasma currents that help confine the plasma. One of the older vertical antennas was replaced with a new one which runs horizontally to produce the so-called Ion Bernstein waves, studied extensively on the PBX-M project by Masa Ono and Ben LeBlanc, but never on TFTR. The other two vertical launchers were upgraded to improve the efficiency of RF current drive.

Promising Physics

The key objective of magnetic confinement is to prevent particles and energy from being transported out of the plasma. During TFTR's last run period, TFTR physicists were able to create powerful transport barriers using the enhanced reversed shear (ERS) mode of operation. ERS involves the use of a novel magnetic field configuration which dramatically reduces plasma turbulence, resulting in a three-fold increase in the central plasma density and the reduction of particle leakage by a factor of fifty. So far ERS has been successful in taming instabilities in only part of the plasma for a limited range of conditions. During the ERS experiments, physicists noted that the barriers created steep pressure gradients, i.e., regions in the plasma where the pressure changes rapidly with position.

"We have been looking for a way to control the location and magnitude of these pressure gradients," said Hawryluk. "We believe that Ion Bernstein waves can do that for us, therefore we plan to repeat the PBX-M experiments on TFTR with hotter, more powerful plasmas. The Ion Bernstein experiments will be challenging, but if this technique works, it will have major ramifications for the design and operation of fusion power reactors," he continued.

The Ion Bernstein wave experiments will be the highest priority for the run period. Initially these studies will be conducted with deuterium plasmas to allow greater flexibility with a large number of plasma shots. If successful, the waves will be launched into high-power D-T plasmas later in the run period.

Plans for the run period were developed in early December by means of a series of "run assessments" meetings in which TFTR staff discussed the upcoming run. Since then, staff have been busy conditioning neutral beams and the RF systems, and otherwise preparing the machine for the exciting work that will begin after the holidays. ●

TFTR Run Schedule for 1997:
January, February, March

HOTLINE

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The **HOTLINE** is issued by the Princeton Plasma Physics Laboratory, a research facility supported by the United States Department of Energy. It is primarily an internal publication. Correspondence and requests to reprint material should be directed to the Editor, PPPL HOTLINE, P.O. Box 451, Princeton, NJ 08543; Interoffice correspondence should be addressed to Room B366, LOB Bldg., C-Site; fax 609-243-2751; telephone 609-243-2757; e-mail pwieser@pppl.gov

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(Majority of the team is pictured on page 1)

Beer Receives Prestigious Simon Ramo Award

By Patti Wieser

Lauded for "doctoral thesis work of outstanding scientific quality," Michael Beer, a young scientist at PPPL, recently garnered the 1996 Simon Ramo Award from the American Physical Society (APS).

Beer, who is at PPPL through a postdoctoral research appointment, received the prize in November during the annual APS meeting in Denver, Colorado. The award, given to one individual each year, provides recognition to "exceptional young scientsts who have performed original doctoral thesis work of outstanding scientific quality and achievement in the area of plasma physics." Beer was cited "For fundamental contributions to the development of simulations of gyrofluid equations for studying tokamak plasma turbulence, including a novel fluid model of trapped electrons that led to realistic comparisons with experiments."

The award recipient has been at PPPL since 1989, first as a Princeton University graduate student in plasma physics (Ph.D. 1994) and then through an appointment to the U.S. DOE Fusion Energy Postdoctoral Research Program administered by the Oak Ridge Institute for Science and Education. He will become a member of PPPL's Theory Division beginning in January, 1997. Beer received a bachelor's degree in aerospace engineering from the University of Michigan in Ann Arbor in 1989.

Michael Beer

His thesis advisor, PPPL Research Physicist Greg Hammett, said of Beer, "It is a joy to work with someone as bright, deep-thinking, and hard-working as Mike. His work has led to sophisticated computer simulations and theories that we believe are a major advance in understanding the complex problems of plasma turbulence. His work has been particularly useful in trying to understand exciting, recently discovered methods of turbulence suppression. We plan to build on this work to see if one of these turbulence suppression methods can lead to a less-expensive fusion power plant design."

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Beer

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Added Theory Division Head Bill Tang, "It is very important to be able to attract, train, and assimilate the best and brightest young talent into the plasma sciences. The addition of Dr. Beer to PPPL's research staff is a significant positive step in that direction."

The Simon Ramo Award was established in 1985 to honor the many outstanding contributions to the science and application of electromagnetism by the late Simon Ramo, who was co-founder of the Ramo-Woolridge Corporation and the TRW electronics and computer company. The award is supported by donations from TRW, Inc. Recipients receive $1,500, a citation, and up to $500 for travel to attend the annual APS meeting. ●

Response Statement to *Science* Magazine Article

An article in the December 6, 1996, issue of ***Science*** *magazine discusses a new computer model which predicts that the proposed International Thermonuclear Experimental Reactor (ITER) will not demonstrate "ignition." The broad consensus of the scientific community is that neither this nor any other existing theoretical model has the precision necessary to accurately predict the performance of a complex scientific experiment such as ITER. For this reason, the ITER design team has used a variety of complementary tools, based on both theory and extrapolation of current experiments, to predict performance.*

The goal of producing fusion energy on earth is one of the world's great scientific challenges. For decades fusion scientists have struggled to confine the ultra hot plasma needed to produce fusion in a magnetic container, often progressing dramatically through trial and error guided by scientific intuition and theory. The plasma has frustrated and fascinated researchers by developing turbulence that allowed the hot plasma to leak across the magnetic field and out of the container. During the past several years a major breakthrough has occurred as scientists have discovered that they can manipulate the magnetic container to prevent the development of turbulence and virtually stop the leakage of plasma. These exciting developments are a product of advances in the scientific understanding of plasma which has occurred over the long history of the fusion and plasma science program: for the first time plasma scientists are developing first principles models of the complicated processes which cause the leakage of energy across the magnetic field. This understanding, which is still being developed, may open the door for new techniques that could improve the eventual prospects for the widespread application of energy from magnetic fusion.

One of the theories of energy leakage, incorporated into the computer model by Drs. William Dorland and Michael Kotschenreuther at the University of Texas, Austin, is the subject of the article in the December 6 issue of Science. This new theory has been very successful in describing the energy confinement in the hottest central portions of tokamak confinement machines. It does not accurately describe the complex region close to the walls of the magnetic container, which is a crucial region to understand in order to predict the overall containment properties of a particular fusion experiment. Thus, scientists are making progress but are not yet reliably able to predict energy confinement in fusion experiments solely on the basis of a theoretical model.

The United States, Europe, Japan, and Russia are in the process of designing ITER, an experiment to study energy production from a controlled fusion reaction. The theory by Drs. Dorland and Kotschenreuther predicts that the present ITER design will not achieve ignition, a condition where energy input from outside can be turned off and the plasma will continue to produce energy. Because of uncertainties of the theory, this prediction is not conclusive. Nevertheless the theory has been valuable in identifying key areas where scientific progress is required to enable scientists to predict the containment properties of future experiments and experiments will continue this year to test critical features of the Dorland-Kotschenreuther and other theoretical models. A review of the ITER design by the Fusion Energy Science Advisory Committee has been planned and will be carried out early next year.

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Happy Holidays! PPPL Laboratory Break: Monday, December 23 through Wednesday, January 1.